Supporting Information for

Multi-decadal trends and variability in burned area from the 5th version of the Global Fire Emissions Database (GFED5)

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Table S1. The GFED5 burned area product derived in this study contains multiple data layers, including 4 burning types: Normal, Cropland, Peatland, Deforestation. The Normal type burned area is further divided into different sub-layers based on the land cover type (LCT) and then aggregated into 4 vegetation classes. The modified MODIS LCTs, which are derived from the vegetation maps by van Wees et al. (2022), are used together with the peatland mask and deforestation mask to separate these burned area layers.

	GFED5 burning area data		Modified MODIS LCT		
Type	LCT	Aggregated vegetation class	Name	Abbreviation	Code
Normal	Water	Other	Water	Water_W	0
	Boreal forest	Forest	Boreal forest	Boreal_F	1
	Tropical forest	Forest	Tropical forest	Tropic_F	2
	Temperate forest	Forest	Temperate forest	Temper_F	3
	Temperate mosaic	Shrub/Savanna	Temperate mosaic	Mosaic_FS	4
	Tropical shrublands	Shrub/Savanna	Tropical shrublands	Tropic_SH	5
	Temperate shrublands	Shrub/Savanna	Temperate shrublands	Temper_SH	6
	Temperate grasslands	Grass	Temperate grasslands	Temper_G	7
	Woody savanna	Shrub/Savanna	Woody savanna	Woody_SA	8
	Open savanna	Shrub/Savanna	Open savanna	Open_SA	9
	Tropical grasslands	Grass	Tropical grasslands	Tropic_G	10
	Wetlands	Other	Wetlands	Wetland_W	11
	Urban	Other	Urban	Urban_U	13
	Snow/Ice	Other	Snow/Ice	Snow_SI	15
	Barren	Other	Barren	Barren_B	16
	Sparse boreal forest	Forest	Sparse boreal forest	Boreal_FS	17
	Tundra	Grass	Tundra	Tundra_T	18
Cropland	-	-	Tropical crop	Tropic_C	12
	-	-	Temperate crop	Temper_C	14
	-	-	Boreal crop	Boreal_C	19
Peatland	-	-	All LCTs within the peatland mask		
Deforestation	-	-	All LCTs within the deforestation mask		

Table S2. A summary of reference tiles in each GFED region. See Table 1 for a detailed description of the data sources. BA_{hr} and $BA_{MCD64A1}$ represent the total burned area associated with all reference tiles in each region, as recorded by Landsat/Sentinel-2 and MODIS (MCD64A1), respectively.

Region	Data source	Number of tiles	BA_{hr} (Mha)	$BA_{MCD64A1}$ (Mha)
BONA	NBAC 2018	1	1.85	2.80
TENA	C3S, USA, GLB0314, GLB08	83	0.58	0.69
CEAM	C3S, GLB0314, GLB08	10	0.15	0.06
NHSA + SHSA	C3S, GLB0314, GLB08	90	1.85	1.77
EURO	C3S, GREECE, GLB0314, GLB08	25	0.28	0.29
MIDE + NHAF	AFRS2	24	2.90	1.39
SHAF	AFRS2	21	2.29	1.37
BOAS	C3S, GLB0314, GLB08	19	0.63	0.45
CEAS	C3S, GLB0314, GLB08	13	0.25	0.21
SEAS	C3S, GLB0314, GLB08	23	2.49	0.66
EQAS	IDNS2Ref	1	0.02	0.01
AUST	C3S, GLB0314, GLB08	92	7.73	7.30

Table S3: MODIS Aqua and Terra (MODIS A&T) conversion factors (γ_{crop}) for each crop type were derived using high resolution burned area data in different reference areas. Table edited from Hall et al., submitted.

Crop type	MODIS A&T γ_{crop}	Reference areas (median values)
Winter wheat	1.76	Ukraine, Russia
Spring wheat	3.30	Russia, Canada, USA
Maize	1.45	Ukraine, Brazil
Sugarcane	1.02	USA, Brazil
Rice	1.58	USA
Generic/Other	1.76	All regions

Table S4. Performance statistics for burned areas derived from Terra only and from ATSR+VIRS relative to GFED5 burned area in 14 GFED regions. The temporal statistics were derived using the regional sum of burned area monthly time series. The spatial statistics were derived from the all-year mean burned area in each 0.25° grid cell. r^2, SLP, nMB, and nMSE represent the coefficient of discrimination, slope, normalized mean bias, and normalized mean squared error, respectively.

Region	Terra only (2003-2020)								ATSR+VIRS (2001-2010)							
	Temporal				Spatial				Temporal				Spatial			
	r^2	SLP	nMB	nMSE	r^2	SLP	nMB	nMSE	r^2	SLP	nMB	nMSE	r^2	SLP	nMB	nMSE
BONA	0.99	1.07	0.05	0.15	0.93	0.99	0.05	0.93	0.83	0.79	-0.20	0.52	0.07	0.29	-0.13	5.65
TENA	0.95	1.24	0.30	0.36	0.82	1.30	0.30	1.48	0.65	0.54	-0.22	0.41	0.02	0.25	-0.19	4.41
CEAM	0.99	1.36	0.39	0.61	0.87	1.46	0.38	1.05	0.90	0.83	-0.24	0.48	0.28	0.79	-0.12	1.77
NHSA	0.99	1.11	0.04	0.15	0.96	1.02	0.01	0.38	0.95	0.96	-0.15	0.27	0.59	0.66	-0.14	1.13
SHSA	0.98	0.93	-0.08	0.16	0.86	0.87	-0.10	0.55	0.92	0.99	-0.16	0.34	0.31	0.80	-0.17	1.76
EURO	0.97	1.20	0.21	0.36	0.94	1.20	0.21	1.43	0.66	0.64	-0.18	0.68	0.07	0.55	-0.11	8.29
MIDE	0.93	1.30	0.52	0.66	0.90	1.43	0.52	4.40	0.83	0.59	-0.38	0.60	0.07	0.27	-0.36	9.38
NHAF	0.99	1.04	0.01	0.14	0.93	1.01	0.00	0.47	0.96	0.99	-0.09	0.26	0.72	0.94	0.01	0.97
SHAF	0.98	1.04	0.06	0.15	0.85	1.03	0.06	0.45	0.95	0.93	-0.09	0.26	0.26	0.76	-0.08	1.35
BOAS	0.99	1.20	0.16	0.37	0.97	1.18	0.16	0.87	0.90	0.67	-0.25	0.65	0.23	0.47	-0.26	3.20
CEAS	0.94	0.66	-0.29	0.42	0.80	0.63	-0.29	0.86	0.78	0.68	-0.21	0.48	0.14	0.52	-0.23	2.40
SEAS	0.94	0.85	0.02	0.33	0.73	0.83	0.01	0.87	0.88	0.88	-0.14	0.48	0.55	0.77	-0.14	1.26
EQAS	0.98	0.93	-0.09	0.21	0.75	0.92	-0.15	0.97	0.93	0.89	-0.16	0.40	0.37	0.77	0.09	1.97
AUST	0.99	1.04	0.01	0.11	0.98	1.00	0.01	0.27	0.89	0.90	-0.08	0.33	0.75	0.87	0.02	0.90

Figure S1. Flowchart of the GFED5 burned area algorithm. Terra only data and parameters are with the subscript *T*.
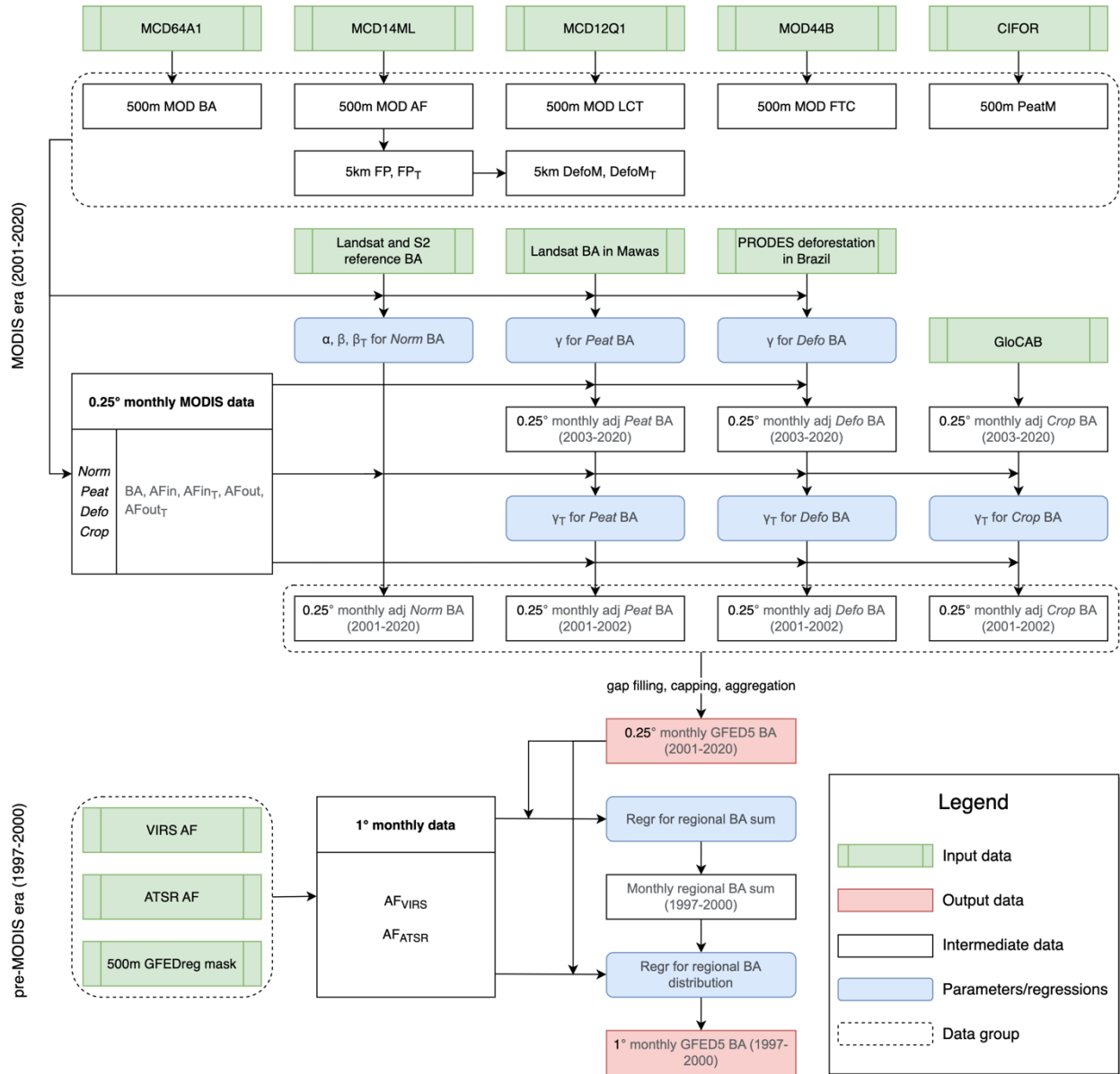
Figure S2. Comparison of regional sums of burned area from GFED5 for 2001-2020, which used active fire data from both Terra and Aqua MODIS for adjustment, and the burned area from the adjustment based on Terra MODIS only. The Aqua data are only available starting from 2003.
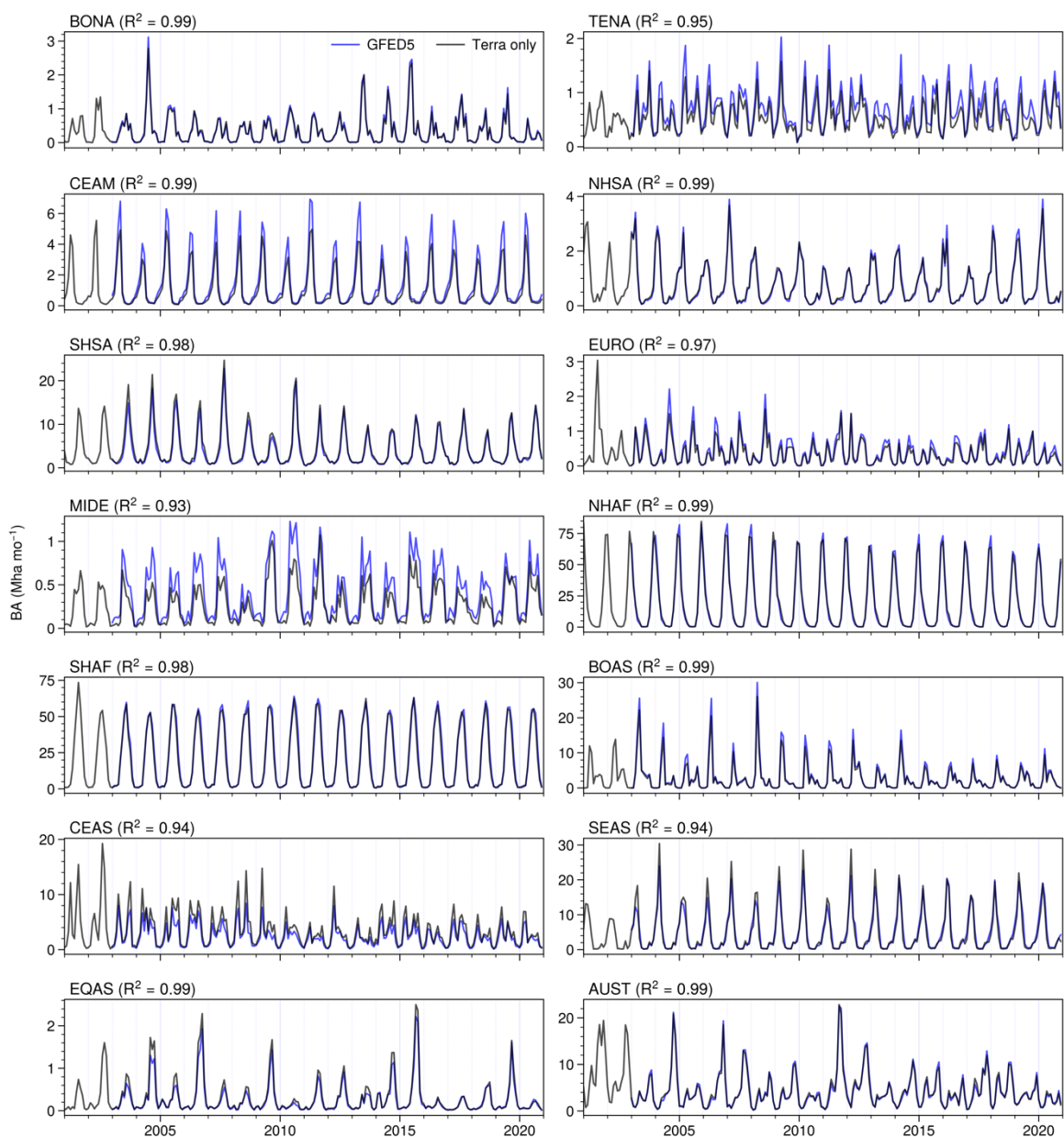
Figure S3. Comparison of deforestation area (in Legal Amazon of Brazil), peatland burned area (in peatlands of MAWAS study area, Indonesia), and cropland burned area (global sum) derived using active fire areas (AF) recorded by both MODIS (Terra and Aqua, T+A) and by Terra MODIS only (see Sec. 2.4.4 for detailed description of the algorithm). Observational and reference datasets, including deforestation area from PRODES, peatland burned area in MAWAS recorded by Landsat, and cropland burned area from GloCAB, are also shown for comparison.
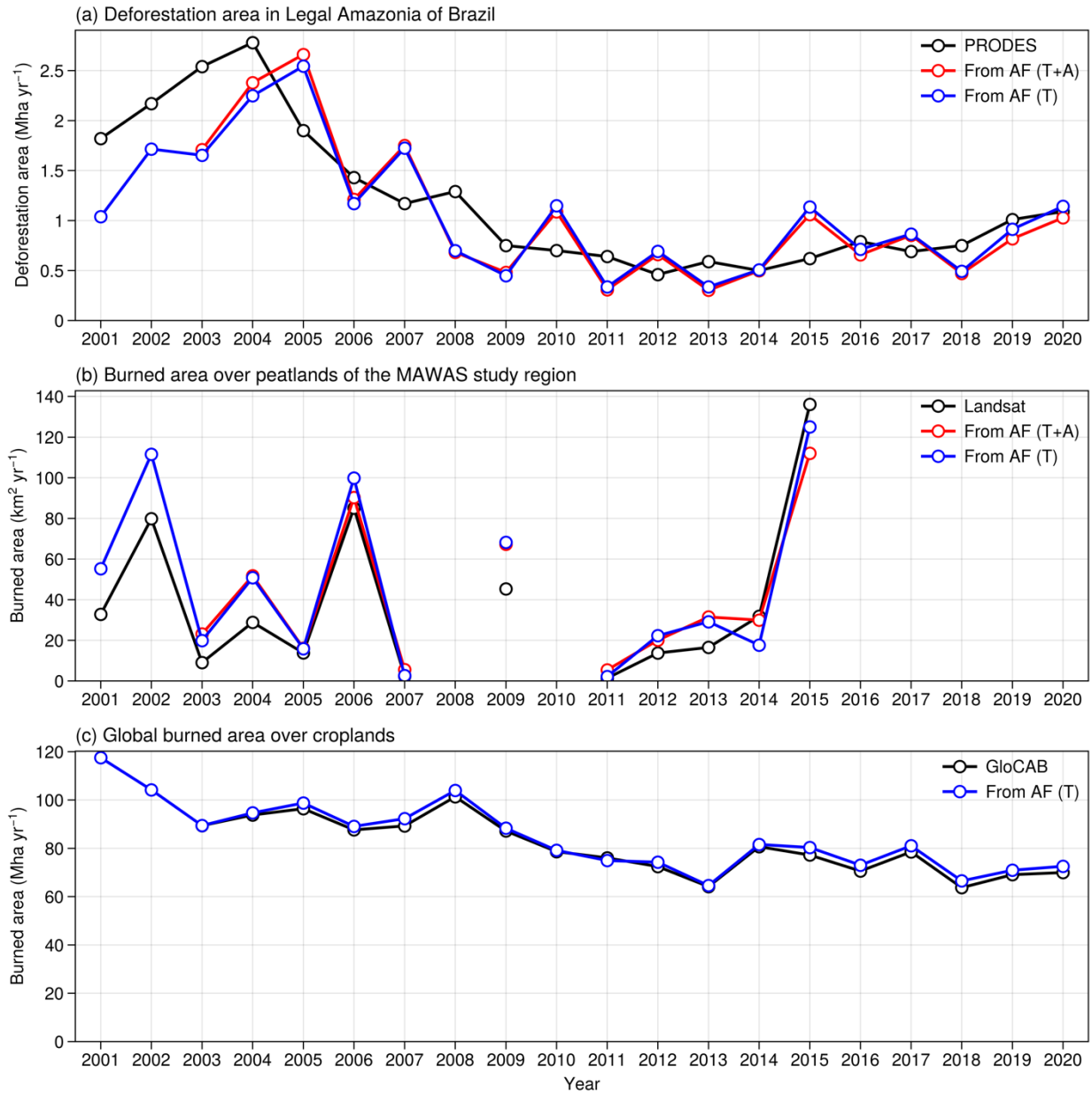
Figure S4. Comparison of regional sums of burned area from GFED5, and the burned area derived based on a scaling approach using ATSR and VIRS active fires (ATSRVIRS, for 1997-2010 only). The VIRS data are used in Africa (NHAF, SHAF), Southeast Asia (SEAS), Equatorial Asia (EQAS), and Australia (AUST) for all years except 1997. The ATSR data are used in other regions for these years, and in all GFED regions for 1997 (when VIRS data are unavailable).
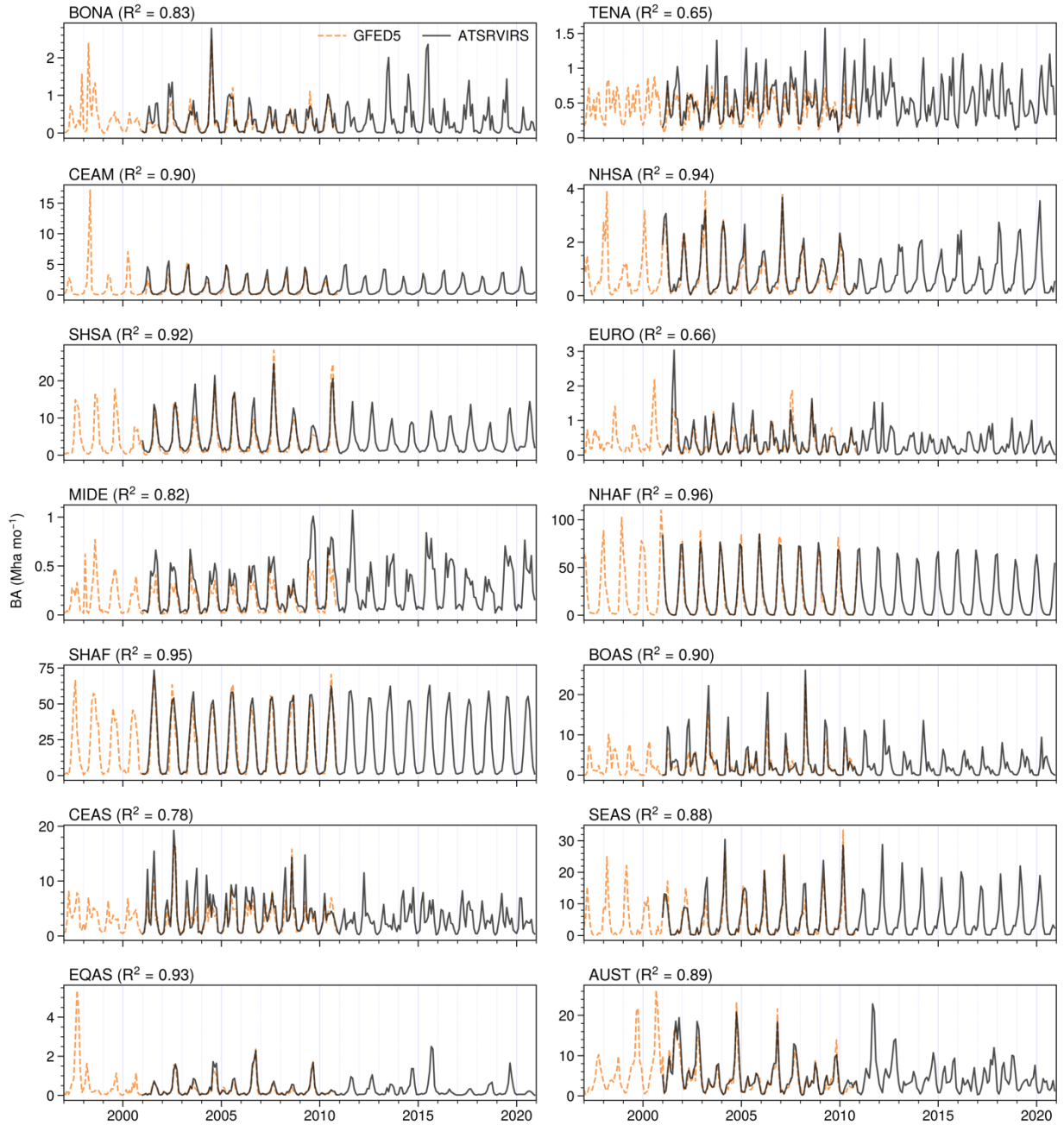
Figure S5. A Hovemoller chart showing the monthly Z-score of GFED5 burned area at each 0.25° latitudinal band. The unitless Z-score, or the normalized anomaly, is defined as the $(v-m)/std$, where v represents the monthly burned area, m represents the climatological (1997-2020) monthly mean burned area, and std represents the standard deviation of interannual variability.
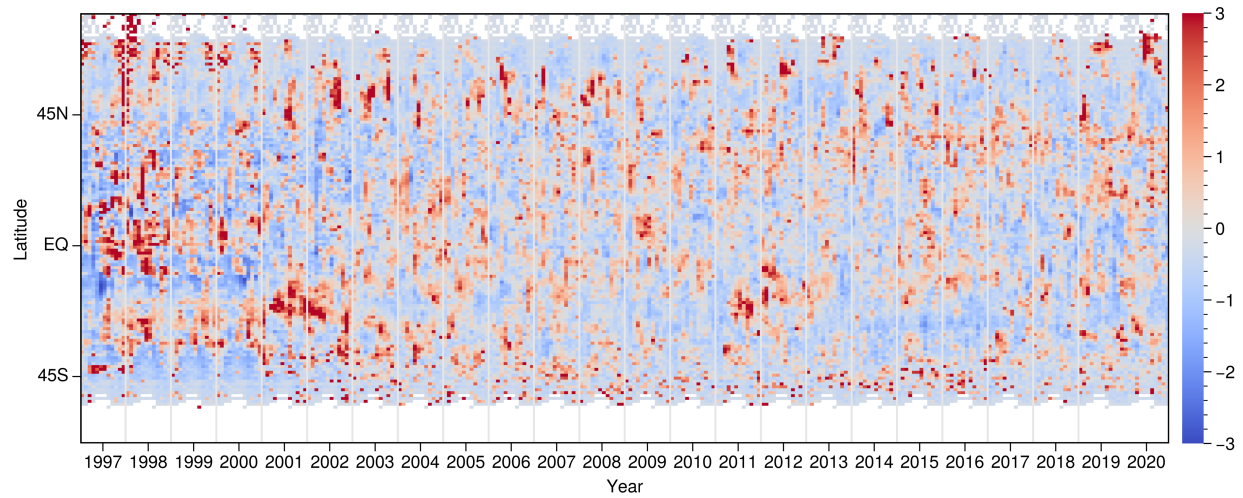
Figure S6. Global map of GFED5 burned area, averaged over 2001-2020, for each category defined by burning type and land cover type group (see Table S3 for detail): (a) Forest, (b) Shrub and savanna, (c) Grass, (d) Crop, (e) Peat, and (f) deforestation.
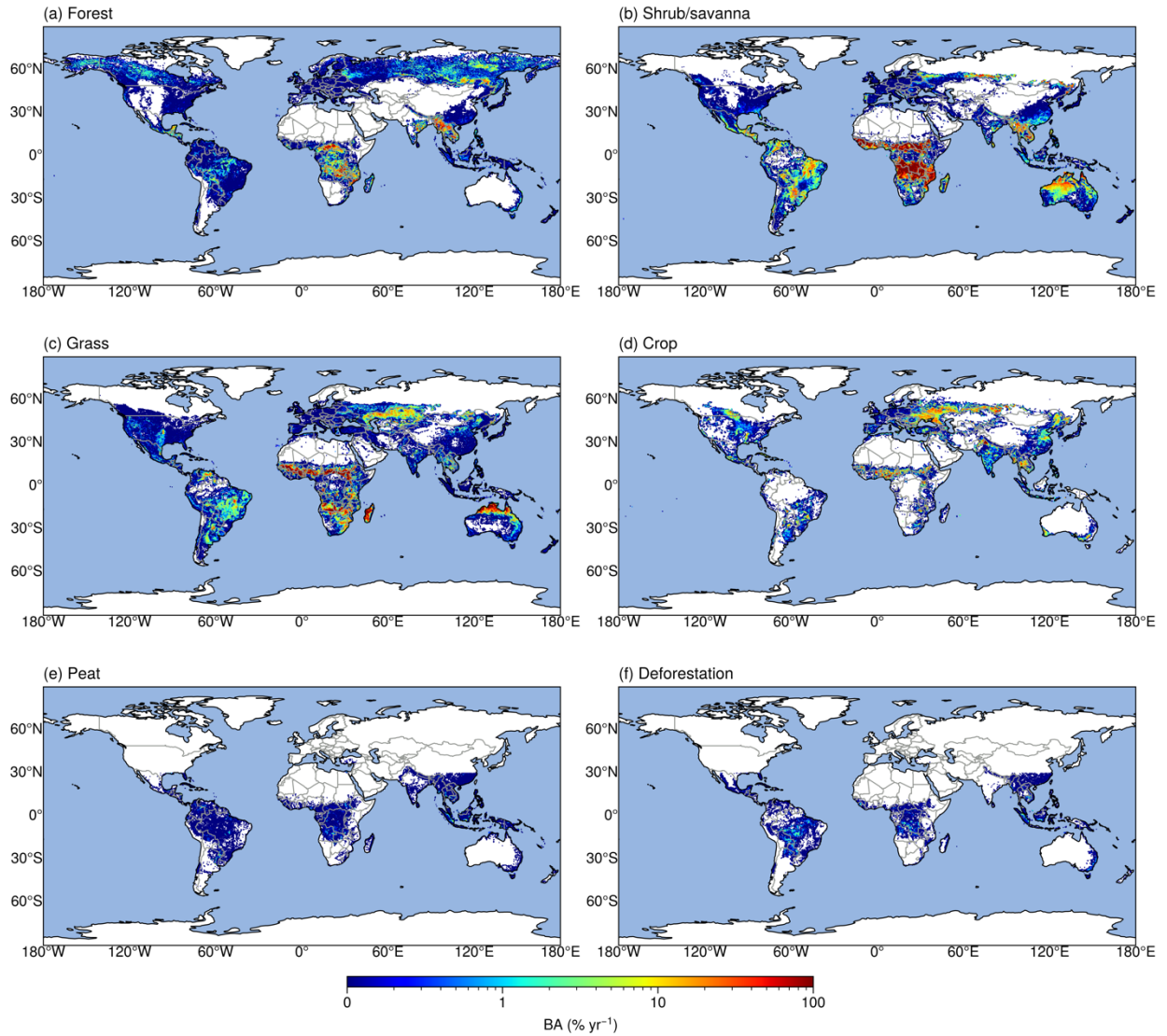
Figure S7. Annual time series of global burned area enhancement ratio, defined as the increment (normalized by the MCD64A1 burned area) from MCD64A1 to GFED5.
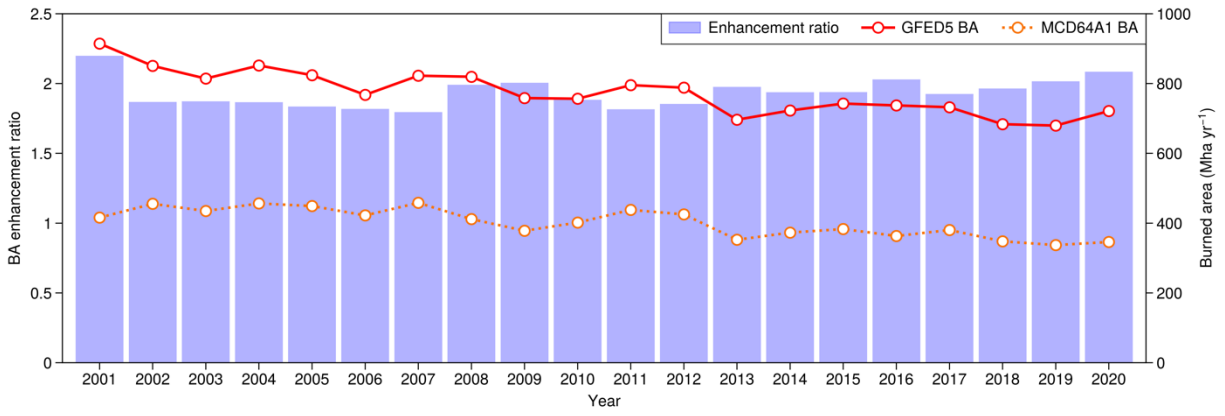
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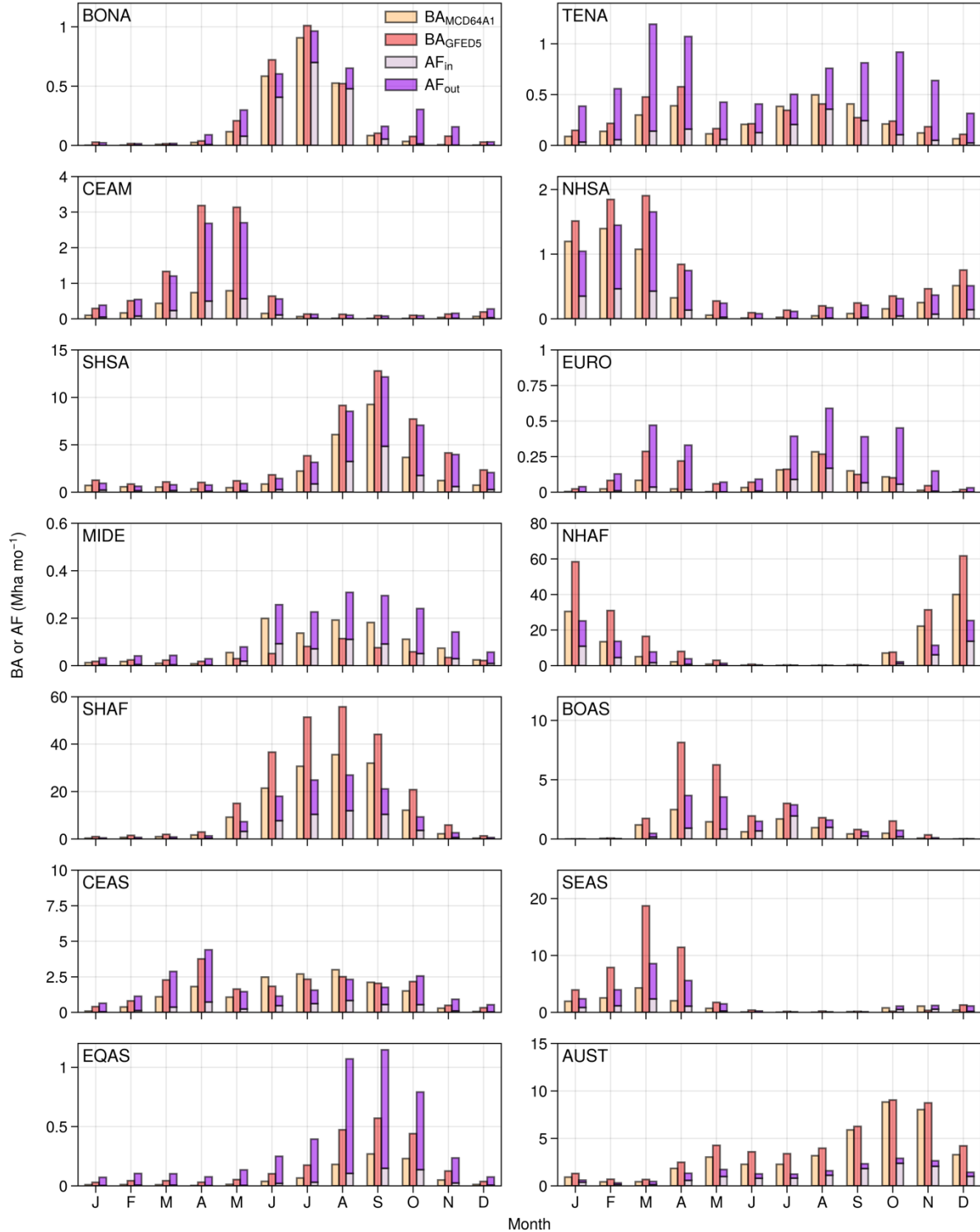
Figure S9. The mean fractional tree cover (FTC) associated with MODIS burned area and active fire pixels. Each data point represents the mean monthly value, averaged in each GFED region over the 7-month period from 3 months before the peak burning month to 3 months after the peak burning month, for the 2001-2020 time period. In many areas, fires burn into areas with higher fractional tree cover later in the fire season.
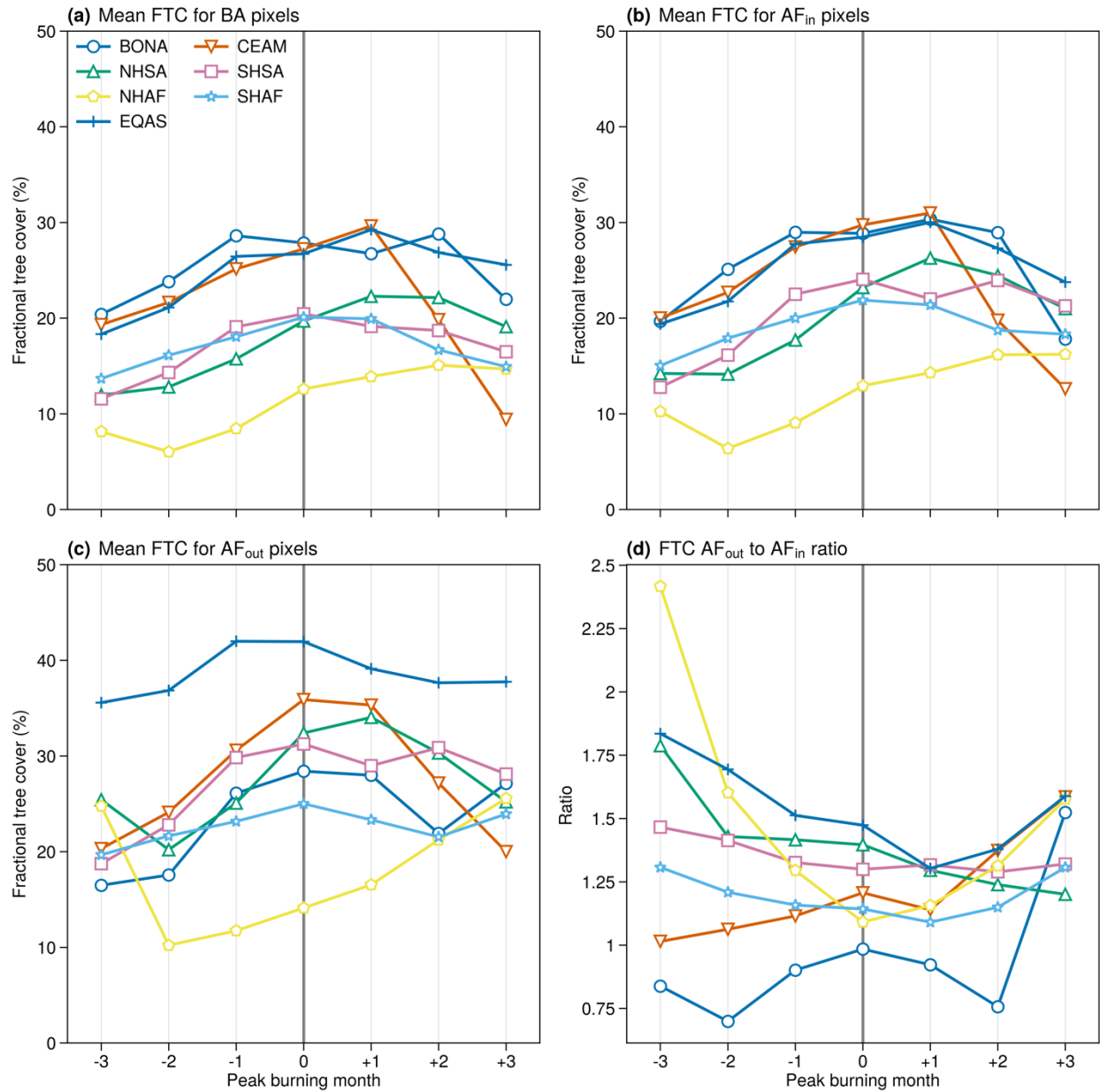
Figure S10. Comparison of annual burned area from MCD64A1, GFED5 and Landsat in (a) Mawas, Indonesia and (b) CONUS. The lighter-colored bars for MCD64A1 and GFED5 in panel (b) represent the burned area portion in cropland. Cropland burned area is displayed separately because burned area mapping using Landsat has been shown to be challenging in many agricultural and rangeland ecosystems and is likely to be underestimated (Vanderhoof et al., 2017).
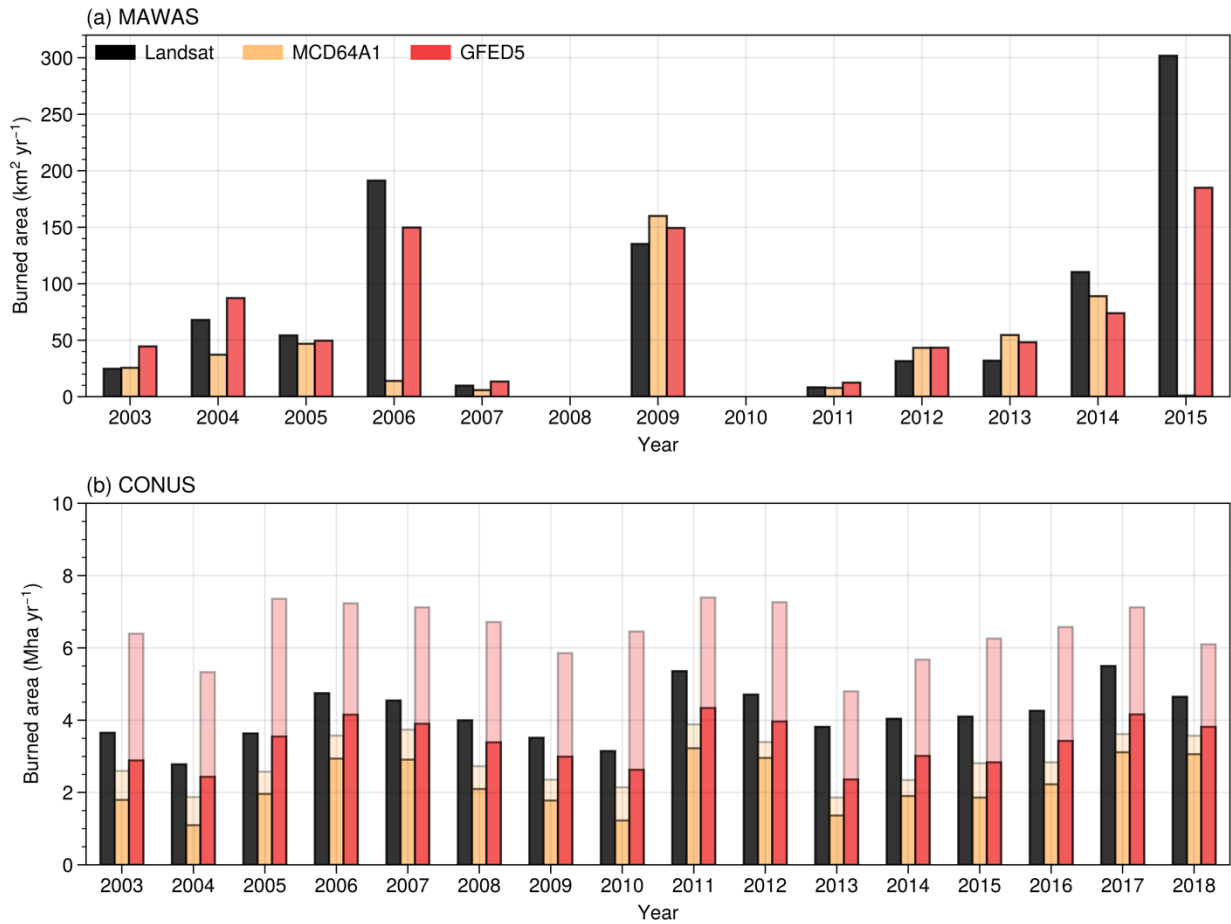
Figure S11. Comparison of monthly burned area in Russia for 2020 from MODIS MCD64A1 and GFED5. The Sentinel-2 derived burned areas (S2) from the RUSS2 dataset (see Table 1) for spring months are also shown.
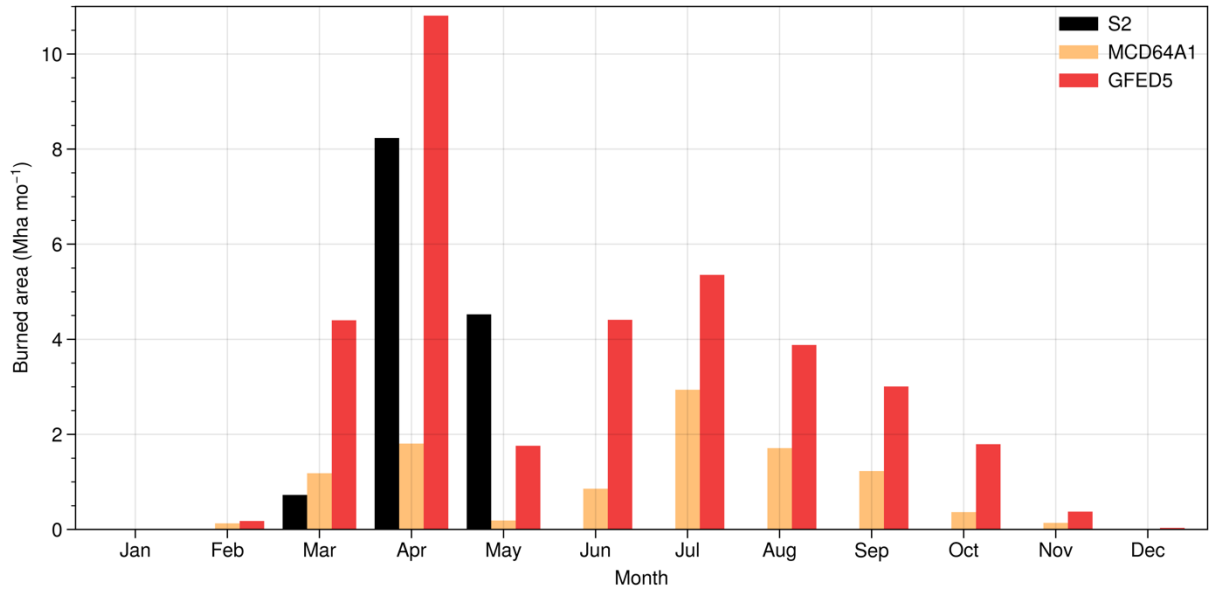
Figure S12. Mean annual burned area (in units of Mha yr^{-1}) summed over the globe and different GFED regions, averaged from 2001 to 2020. For each region, the left and right bars show the burned area from MODIS MCD64 and GFED5, respectively.
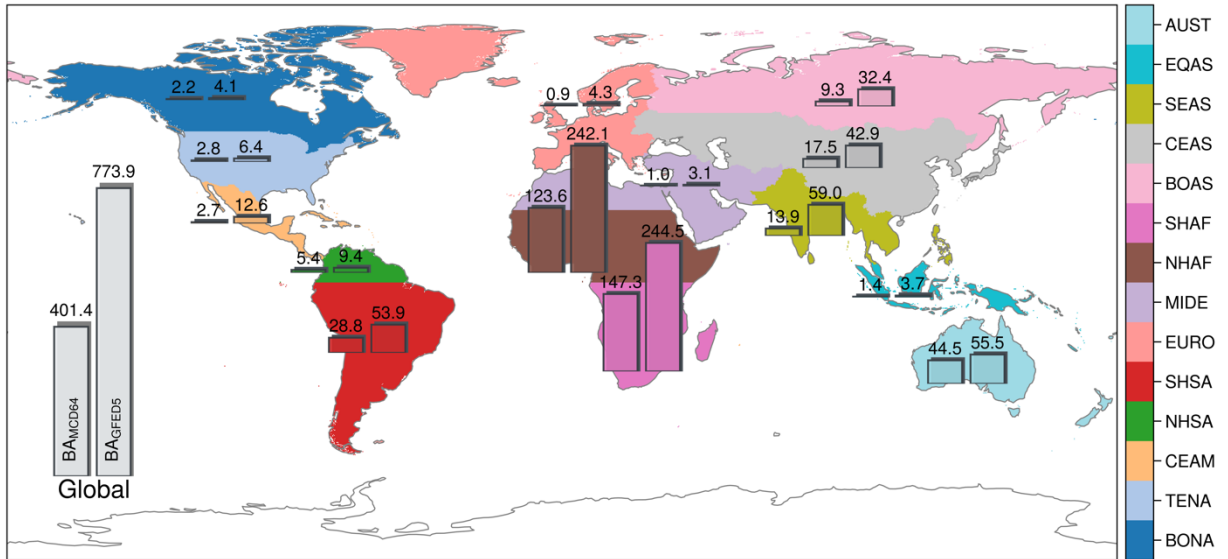
Figure S13. Mean annual active fire area (AF) from MODIS summed over the globe and different GFED regions, averaged from 2001 to 2020. For each region, the left and right bars show active fire area within the burned area (AF_{in}), and active fire area outside of the burned area (AF_{out}), respectively.
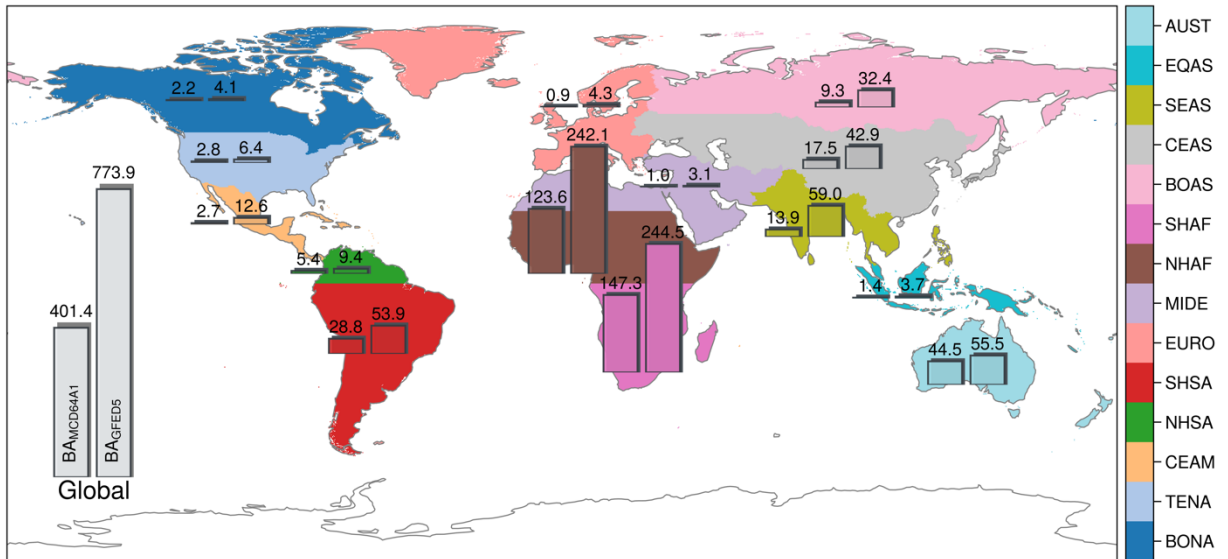
Figure S14. Total burned area (BA) from MCD64A1 and GFED5, as well as the enhancement ratio (Enr), defined as $(BA_{GFED5} - BA_{MCD64A1})/BA_{MCD64A1}$, for different burning types. All the values are averaged from 2001-2020.